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The Effects of Scavenging on Waste Nitrous Oxide Concentrations in Veterinary Operating Room Air

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Veterinarians, their assistants, and animal researchers should consider the potential health hazards of chronic exposure to the inhalational anesthetic, nitrous oxide. Recent studies suggest that long-term human exposure to nitrous oxide can be associated with increased general health problems and reproductive difficulties. These adverse human health effects include spontaneous abortion, congenital abnormalities, kidney disease, liver disease, and neurologic disease. The exposure level of medical and dental personnel to nitrous oxide in operating and treatment room air is well documented. There are, however, few reports of

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the potential hazard to veterinary personnel. This study was conducted to determine the exposure levels to nitrous oxide in a veterinary surgery. Real-time analyses were obtained utilizing infrared spectrophotometry. Measurements were made both during scavenging and not scavenging of the waste anesthetic gas. The mean level of nitrous oxide during scavenging was significantly different from the mean during not scavenging. Furthermore, the 95 percent upper confidence limit for the scavenged mean was within the 25 parts per million standard for nitrous oxide recommended by the National Institute for Occupational Safety and Health. The 95 percent upper confidence limit for the not scavenged mean was well above that standard. Protection of veterinary personnel and animal researchers from chronic exposure to nitrous oxide vapors, therefore, seems advisable and achievable. Complete waste anesthetic gas management and periodic monitoring programs should be established to protect personnel involved.

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PREFACE

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This article represents the first documentation of nitous oxide levels in veterinary surgeries under controlled conditions, and the effects of scavenging on those waste gas levels.

INTRODUCTION

We live in an age of increasing awareness and concern about occupational health and diseases associated with environmmental pollution. Attention has been called to the possible adverse effects of trace anesthetic gases in human surgeries (13). Veterinarians, their assistants, and animal researchers who use gaseous anesthetics on a regular basis should also consider the potential environmental hazards posed by these chemicals.

Interest in trace anesthetic gases was stimulated in 1967 by a survey of 303 Russian anesthesiologists who reported a high incidence of nausea, irritability, headache, fatigue and pruritus, and an alarming rate of spontaneous abortions (40). Subsequent to this report, a number of human epidemiologic studies, and laboratory animal experiments have been conducted in an attempt to identify any prominent health effects associated with chronic exposure to waste anesthetic gases.

The major adverse human health effects identified by the epidemiologic surveys were abortion and congenital abnormalities. An increased incidence of spontaneous abortion in exposed female workers (2, 5, 6, 7, 16, 21, 22) and of congenital abnormalities among their children (10, 11, 12, 21, 22) were found. The same increases among the unexposed wives and children of exposed men were also noticed (2, 6, 7, 22). These human epidemiologic surveys, furthermore, described effects on fertility (21), hepatic and renal diseases (10, 11, 39), the central nervous system (39, 40) and the risk of cancer (4, 6, 12) following exposure to anesthetic gases. More specifically, results from a recent controlled survey of more than 61,000 dentists and their assistants suggest that long-term exposure to nitrous oxide can be associated with increased general

health problems (8). As in the previous surveys, these problems included increased rates of reproductive difficulties, cancer, liver disease, kidney disease, and neurologic disease.

Experimental evidence from laboratory animal studies is supportive of the suggestion that health hazards are actually caused by nitrous oxide exposure. Fetal resorption has occurred in rats following exposure to nitrous oxide at levels within the range of occupational exposure (19). Nitrous oxide has also caused teratogenic effects in pregnant rats (24). Furthermore, it has been suggested that nitrous oxide, when administered simultaneously with halothane to rats at occupational levels, might result in a synergistic cytologic or reproductive effect (29). Such a regimen has been shown to result in dose-dependent increases in cytogenetic aberrations in both bone marrow and spermatogonial cell populations, as well as a decrease in ovulation and implantation efficiency, and retardation in fetal development (12). Studies in rats and mice have also shown depression of splenic antibody-producing cells associated with 24 hours of treatment of these rodents with nitrous oxide (20, 41). In another sudy, prolonged exposure to nitrous oxide resulted in lymphopenia and neutrophilia (17). Finally, myeloneuropathy associated with nitrous oxide exposure or abuse (25, 26) is thought to be related to an interaction of nitrous oxide with vitamin B_{12} (1, 8, 15, 34).

The first report of nitrous oxide concentrations in human operating rooms appeared in 1969 and described an average exposure level of 130 ppm, with a peak level as high as 428 ppm near the anesthesia machine (27). A 1970 study reported an average nitrous oxide concentration of 7,000 ppm near the face of the anesthesiologist during use of a nonrebreathing system (3). In 1973, levels as high as 9,700 ppm nitrous oxide had been reported in human operatories (9). In dental operatories, nitrous oxide exposure levels as high as 24,000 ppm have been

recorded (18). However, does breathing trace amounts of nitrous oxide in veterinary and animal research facilities constitute a similar personal or personnel hazard? The evidence for or against is scanty. There have been few scientifically documented reports of measurements of nitrous oxide in veterinary surgeries. One uncontrolled survey of U. S. Air Force veterinary surgeries reported nitrous oxide concentrations ranging from 6 to 270 ppm (31). In 15 of 20 samples collected during that survey, the time-weighted average nitrous oxide concentration exceeded the maximum recommended by the National Institute for Occupational Safety and Health (13). Another limited survey showed concentrations of 18.6 to 35 ppm of nitrous oxide in two veterinary surgical procedures done with nitrous oxide and halothane simultaneously, and administered through nonscavenged rebreathing anesthetic circuits (42).

Until the present, therefore, we have looked only at data gathered in human and dental surgeries, along with a few limited surveys conducted in veterinary surgeries, and concluded that efforts should be made to depollute veterinary and animal research preparation, operating and recovery rooms. Consequently, the following study of nitrous oxide concentrations in the operating room air of a veterinary surgery was conducted under controlled conditions. The primary emphasis of this study was to establish analytically determined values of exposure concentrations of nitrous oxide at the breathing zone of veterinary personnel, both during scavenging and not scavenging of the waste anesthetic gas.

MATERIALS AND METHODS

Twelve dogs, ranging in weight from 17.7 - 23.0 kg, were anesthetized for two hours each. The dogs were initially anesthetized with an injectable anesthetic, with maintenance anesthesia produced through inhalational techniques as described by Short (36). Halothane was delivered via a semiclosed system using Copper Kettle and Vernitrol vaporizers. Gas flow rates and vaporizer settings were: 3 liters/min O_2; 3 liters/min N_2O; 1.5% halothane. The dogs' ventilatory patterns were assisted by intermediate positive pressure breathing. The anesthetist judged the depth of anesthesia by monitoring an electrocardiogram. Nitrous oxide concentrations in the operating room air were determined directly by infrared spectrophotometry using a Wilks Miran-1A General Purpose Gas Analyzer (Wilks/Foxboro Analytical, Norwalk CT). The sampling parameters using the infrared spectrophotometer were: wavelength, 4.5 m; slit setting, 1.0 mm; absorbance range, 0-1.0 units; pathlength, 14.25 m; volume, 5.6 liters; windows, NaCl. Calibration of the infrared spectrophotometer, construction of standard curves and calculations were based on the operation, maintenance and service manual for the instrument (32). The 12 dogs were randomly placed into two groups. One group of six dogs was anesthetized while practicing waste anesthetic gas scavenging techniques, as described by Whitcher and Rock (44), and Manley and McDonell (29). The other group of six dogs was anesthetized without the employment of a waste anesthetic gas scavenging system. Nitrous oxide measurements were taken at four time intervals (4, 36, 68, 100 minutes after the start of the procedure) and at the following four locations in the operating

room: breathing zone, anesthetist; breathing zone, surgeon; breathing zone, dog; and at the operating room exhaust vent. The data collected were statistically evaluated by analysis of variance, and the 95 percent upper confidence limit was determined for each group mean (38).

RESULTS

The data collected in this study are shown in Tables I and II. Results of the statistical analyses are summarized in Table III. The range of nitrous oxide concentrations in 96 air samples measured during scavenging was 1.5 - 38.5 ppm, while the range of 96 measurements during not scavenging was 50.0 - 160.0 ppm. The mean nitrous oxide concentration during scavenging (9.08 ppm) was significantly different ($p<.0001$) from the mean during not scavenging (118.19 ppm). Furthermore, the 95 percent upper confidence limit for the mean of the scavenged group (22.53 ppm) was within the National Institute for Occupational Safety and Health (NIOSH) recommended standard for nitrous oxide of 25 ppm (13). However, the 95 percent upper confidence limit for the mean of the not scavenged group (155.49 ppm) was well above that NIOSH recommended standard. There was no significant difference in nitrous oxide concentrations due to time of measurement. There was, also, no significant difference between the overall position means. The highest mean concentration of nitrous oxide during not scavenging (122.83 ppm) was at the breathing zone, dog (D). In terms of personnel exposure during not scavenging, the surgeon (S) was exposed to a mean of 114.75 ppm nitrous oxide, while the anesthetist (A) was exposed to a mean of 120.45 ppm nitrous oxide. The mean nitrous oxide concentration at the exhaust vent (V) during not scavenging was 114.74 ppm. There was no significant difference between the position means of the scavenged group (D, 12.92 ppm; S, 8.44 ppm; A, 6.99 ppm; V, 7.95 ppm). There were no group X time, position X time, group X position, or group X position X time interactions.

TABLE I. NITROUS OXIDE CONCENTRATIONS (ppm) IN VETERINARY OPERATING ROOM AIR DURING SCAVENGING

Time after start of procedure, min	4	36	68	100
Position [a,b]				
D	14.80±3.13	12.05±3.29	13.23±5.50	11.43±3.18
A	7.27±1.20	7.67±2.25	6.48±1.62	6.53±1.69
S	8.68±2.14	8.78±2.25	8.20±1.22	8.10±1.66
V	6.52±1.56	8.05±1.79	8.65±1.93	8.58±1.54

[a]Breathing zone, dog (D); breathing zone, anesthetist (A); breathing zone, surgeon (S); exhaust vent (V)

[b]Each value is the mean of six observations, ± standard error of the mean

TABLE II. NITROUS OXIDE CONCENTRATIONS (ppm) IN VETERINARY OPERATING ROOM AIR DURING NOT SCAVENGING

Time after start of procedure, min	4	36	68	100
Position [a,b]				
D	121.38± 8.11	124.80±17.20	118.63±12.77	126.52± 9.51
A	112.25±14.00	126.92± 8.38	127.35± 9.49	122.80± 8.14
S	116.22±11.38	117.92±16.10	112.55±15.34	112.30±15.42
V	113.83±13.03	117.08± 9.90	115.55±10.26	114.17±10.18

[a]Breathing zone, dog (D); breathing zone, anesthetist (A); breathing zone, surgeon (S); exhaust vent (V)

[b]Each value is the mean of six observations, ± standard error of the mean

TABLE III. GROUP AND POSITION MEANS OF NITROUS OXIDE CONCENTRATIONS (ppm) IN VETERINARY OPERATING ROOM AIR

Group	Scavenged	Not Scavenged
Position mean[a,b]		
D	12.92±1.84	122.83±5.82
A	6.99±0.81	120.45±5.01
S	8.44±0.87	114.75±6.86
V	7.95±0.82	114.74±4.95
Group mean[c,d]	9.08±0.62	118.19±2.83
95% upper confidence limit of the group mean	22.53	155.49

[a]Breathing zone, dog (D); breathing zone, anesthetist (A); breathing zone, surgeon (S); exhaust vent (V)

[b]Each value is the mean of 24 observations, ± standard error of the mean, and averaged across four time intervals with no interactions

[c]Each value is the mean of 96 observations, ± standard error of the mean, and averaged across four positions and four time intervals. There were no group X time, position X time, group X position, or group X position X time interactions

[d]Group means are significantly different ($p<.0001$)

DISCUSSION

Evidence that occupational exposure to nitrous oxide constitutes a health hazard is circumstantial, being based on human epidemiologic surveys and laboratory animal studies. A cause and effect relationship in humans has not been documented. Other factors affecting medical personnel, such as stress, fatigue, and unfavorable working hours may be involved. Nevertheless, the potential harm of the long-term exposure to nitrous oxide should not be ignored.

Nitrous oxide has long been considered the least toxic and most inert of all anesthetic agents. However, much concern has been raised about the many cytotoxic effects of nitrous oxide (37). The possible long-term effects of that cytotoxicity due to nitrous oxide exposure is not yet known. Furthermore, nitrous oxide has been measured in the end-expired air of personnel after working in operating theaters not using a waste anesthetic gas scavenging system, and found to average 20 ppm (33).

To insure personnel safety, NIOSH has recommended in its Criteria Document on Waste Anesthetic Gases and Vapors (13) that a concentration level of 25 ppm should not be exceeded for nitrous oxide. The results of this experiment show, decisively, that veterinary and animal research personnel are subjected to concentrations of nitrous oxide in excess of the standard recommended by NIOSH. However, since there are some indications that the toxic effects of nitrous oxide are time/dose related (30, 23), and since the lag time between exposure and disease may be as long as 20 years (45), there may be no safe level of exposure to nitrous oxide. It, therefore, seems prudent to limit personnel exposure to nitrous oxide to as low a concentration as possible.

It has been shown that dilution ventilation, alone, has no significant effect on reducing waste anesthetic gas concentrations in veterinary surgeries (35). However, in a study at the Veterinary Medical Teaching Hospital, University of California at Davis, nitrous oxide concentrations of 200 ppm were dramatically reduced when scavenging was instituted (43). The results of this study confirms the latter report and clearly demonstrate the effectiveness of anesthetic gas scavenging techniques in reducing nitrous oxide concentrations in veterinary surgeries.

CONCLUSIONS

Without waste anesthetic gas scavenging, nitrous oxide concentrations in veterinary surgeries are well above the NIOSH recommended standard of 25 ppm. With waste anesthetic gas scavenging, nitrous oxide concentrations in veterinary surgeries are within the NIOSH recommended standard of 25 ppm. Protection of veterinary personnel and animal researchers from chronic exposure to nitrous oxide vapors, therefore, seems both advisable and achievable. Complete waste anesthetic gas management and periodic monitoring programs should be established to protect personnel involved.

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